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Research on Numerical Simulation of Crack Propagation Behaviors in Frp Strengthened Concrete Members

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Abstract: This paper mainly uses MFPA analysis system to simulate the crack propagation law of FRP strengthened concrete members, analyzes the crack propagation law of FRP strengthened concrete members, and discusses the influence of bond layer parameters between FRP plate and concrete on the bearing capacity and failure mode of FRP strengthened concrete members under different FRP parameters. It is found that the bond layer of FRP strengthened concrete members and the characteristics of concrete have a great influence on the crack distribution.

1. Introduction

FRP is a kind of composite material, which is composed of resin matrix, fiber and other materials. In recent years, with the continuous development of such composite materials, it has been widely used in the reinforcement engineering of civil engineering. At present, the application of FRP materials in buildings, tunnels and bridges proves that FRP materials are very effective in strengthening concrete. Many scholars have studied FRP, and mainly focused on the strength of FRP reinforced concrete under different conditions, and obtained some results. However, there are still many problems to be explored and solved. So we can use MFPA analysis system to analyze the crack propagation law of FRP strengthened concrete members.

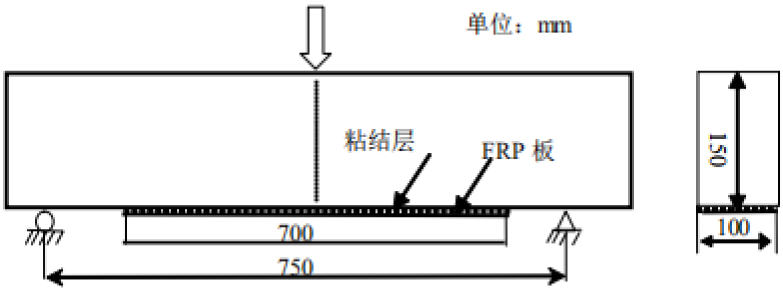
2. Introduction of Mfpa Analysis System

MFPA is a material failure process analysis system, which can simulate the progressive failure process of some materials, such as concrete. In the process of simulating material failure, the system mainly decomposes the material into quadrilateral elements, and assumes that the material satisfies Weibull distribution in the system. The Weibull distribution mainly includes the following parameters: Weibull distribution parameters and shape parameters, which are called Weibull distribution parameters of materials. [1] The shape parameter mainly reflects the degree of dispersion. If the value of this parameter changes from small to large, it means that the distribution of parameters changes from scattered to concentrated. When the shape parameter exceeds 100, the generated values can be considered to be uniformly distributed. The advantage of the numerical simulation of Weibull analysis system is that it fully considers the non-uniformity of concrete, and can also give the numerical simulation process.

3. Numerical Model of Frp Strengthened Concrete Members

3.1 The Establishment of the Model

FRP strengthening concrete is mainly to paste FRP plate on the tensile surface of concrete members, so as to act the tensile force on the concrete members. In the process of strengthening concrete members with FRP, there are generally three different material failure forms: the first is bending failure, mainly including concrete crushing and FRP plate being pulled off; the second is brittle failure, which refers to the FRP plate falling off due to the failure of the bonding surface with concrete, or the crack above the FRP plate; the third type of failure is shear failure, which means that the flexural capacity of the reinforced concrete exceeds the original shear capacity of the concrete. In this paper, the second failure mode, brittle failure mode, is studied and analyzed. [2] There are mainly two types of failure. One is the FRP plate falling off due to the failure of the bonding surface with the concrete, and the other is the FRP plate falling off due to cracks above the FRP plate.The numerical model established in this paper is shown in the following figure:



Dimensions and loading of FRP strengthened concrete members

It can be seen from the above figure that in this model, the concrete beam is 900mm long, 100 mm wide and 150 mm long. The FRP plate is pasted under the supporting beam, and the overall length is 700mm. At the same time, in the model, the elastic modulus of concrete is 25gpa; the overall strength is 3.31 MPa, and the Poisson's ratio is 0.15. The thickness of FRP plate under the supporting beam is 1mm. The overall elastic modulus is 50,000 MPa and the strength is 3350 MPa.

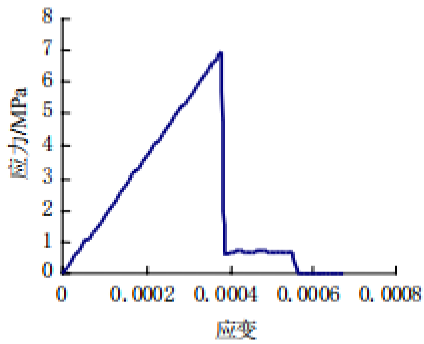
3.2 Stress Strain Relationship of Materials

In the MFPA analysis system, both the FRP plate and the bond layer between concrete and FRP plate are regarded as non-uniform isotropic materials, and the specific parameters are shown in the following table:

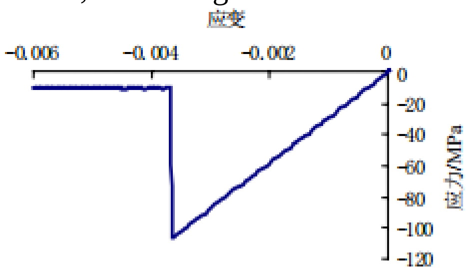
mechanical parameters	FRP	bond layer	concrete
Material homogeneity	200	3	3
Mean value of elastic modulus	50	20	30
Mean value of compressive strength	10050	130,200,400	80,135,160
Poisson's ratio	0.25	0.2	0.15
compression-tension ratio	3	10	10
Coefficient of residual strength	0.1	0.1	0.1

In the simulation process, the selected data is the data in the above table. The elastic modulus of concrete generated by MFPA system is 25gpa, and the strength is 3.31 MPa.

When the meso element axis of concrete and adhesive layer is under tension, its constitutive relation is affected by the following variables: first, the residual strength of the element; second, the minimum principal strain threshold of the element tensile damage; third, the minimum strain threshold of the element separation. Through the calculation of MFPA analysis system, the damage constitutive relation of the element in three-dimensional stress state is as follows:



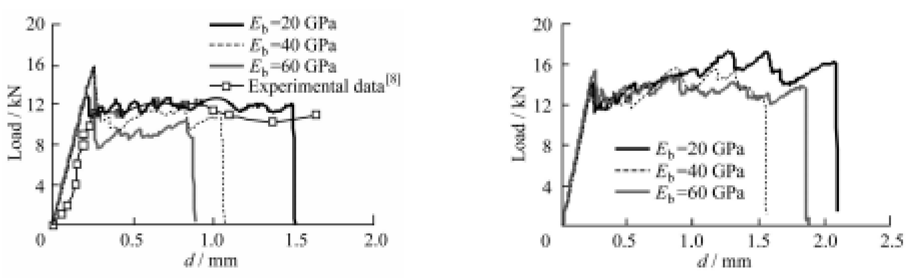
When the element is in compression, the damage constitutive relation is as follows:



3.3 Selection of Material Parameters

This paper mainly explores the influence of bond strength between concrete and FRP slab on the bearing capacity and fracture mode of FRP strengthened concrete members. [3] Therefore, in the process of simulation, different values are selected for the average strength of concrete and adhesive layer. Specifically, when the average meso unit strength of concrete is 8.0 MPa, 13.5 MPa, 16.0 MPa, the corresponding actual strength is 2.0 MPa, 3.31 MPa and 4.0 MPa. As for the bonding layer, when the average strength of meso unit is 13.0 MPa, 20.0 MPa and 40.0 MPa, the corresponding actual strength is 3.25 MPa, 5.0 MPa and 10.0 MPa.

4. Simulation Results



(a) S_b= 13.5 MPa (b) S_b= 20.0 MPa

Fig.1 Load Displacement Curve of Frp Strengthened Concrete Members

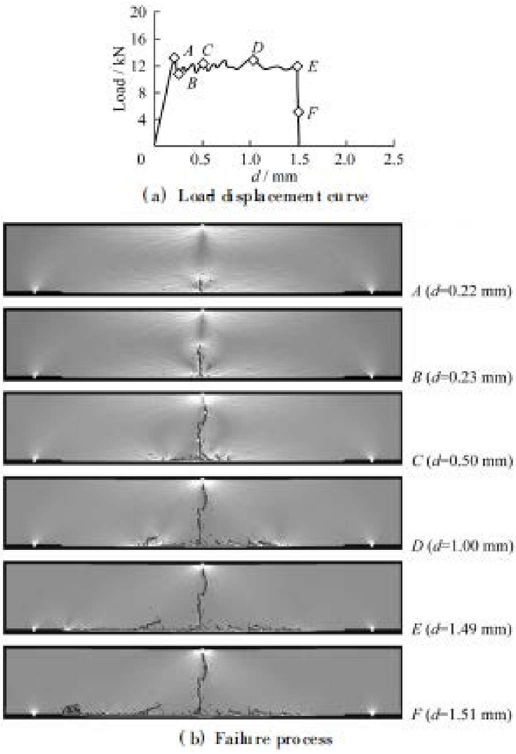


Fig.2 Fracture Process of Concrete Member When the Average Tensile Strength of Adhesive Layer is 13.5 Mpa

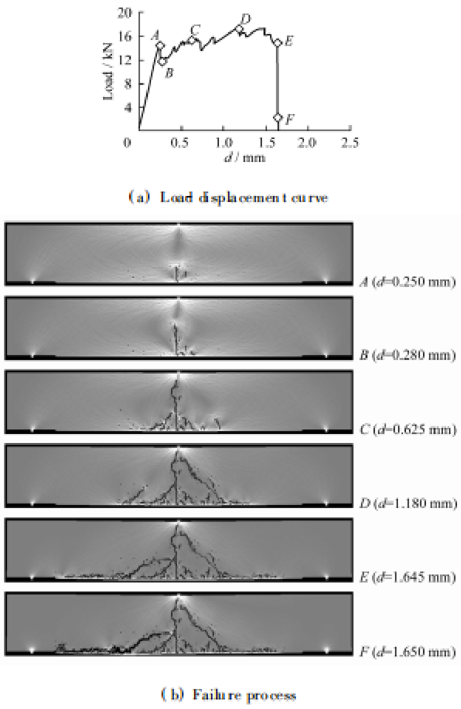


Fig.3 Fracture Process of Concrete Member with Average Tensile Strength of 40 Mpa

Figure 1 shows the load displacement curves of concrete members with different mean elastic modulus of adhesive layer. As can be seen from Figure 1, based on the first peak of the curve, the curve can be divided into two stages, specifically the elastic deformation stage before the peak and the elastic deformation stage after the peak. [4] Figures 3 and 4 show the brittle failure modes of concrete members. The first is that the FRP plate falls off due to the failure of the bonding surface with the concrete; the second is that the FRP plate falls off due to the cracks above the FRP plate.

When the average tensile strength of the bonding layer is 13.5 MPa, the failure mode of the concrete member is the first, that is, the FRP plate will fall off due to the failure of the bonding surface with the concrete. When the elastic modulus of the adhesive layer changes, the crack paths of the concrete members are consistent. In this case, the load displacement curve is mainly softened after the peak value, and this situation will be more obvious with the increase of the elastic modulus of the adhesive layer.

When the tensile strength of the adhesive layer is 20 MPa and 40 MPa, the concrete members mainly show the second failure mode. In this case, the curve after the peak mainly shows a typical strengthening stage. As shown in Figure 2, after the curve reaches the first peak, the load suddenly drops, then slowly rises, and then multiple peaks appear until the concrete member finally loses its bearing capacity. When the elastic modulus of the adhesive layer increases from 40 MPa to 60 MPa, the failure mode of the concrete member does not change, only the load displacement curve changes.

Figure 2 shows the whole failure process of the first failure mode. Before the load reaches the peak value, the tensile stress in the tensile zone of the concrete member will rise continuously, and finally reach the unit tensile strength. At this time, the unit damage will occur, and this damage will lead to the tensile cracks in the concrete member. The whole concrete component is a kind of non-uniform material, so the tension crack does not necessarily appear in the middle of the concrete beam. [5] Under the influence of element damage, the tension cracks continue to expand until the bearing capacity of the concrete member reaches the load. At this time, the load decreases, and the cracks in the concrete member will spread rapidly.

Figure 3 shows the second failure mode. As shown in Figure 3, before the load reaches the first peak, the crack propagation in the concrete member is similar to the first failure mode, and the same is that the tensile crack occurs in the concrete member, which promotes the stress to transfer to the bonding layer. At this time, due to the high strength of the bonding layer, there is no phenomenon that the bonding layer is separated from the concrete. With the increase of the bearing capacity of the concrete members, the cracks continue to expand upward. At this time, the stress at the bottom of the beam of the concrete members begins to expand to both sides, resulting in oblique cracks beside the main cracks. With the increase of the oblique cracks, the cracks finally extend to both ends of the FRP plate. At this time, the bearing capacity of the concrete members is completely lost.

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2).the Key Laboratory of Urban Security and Disaster Engineering , Moe, Beijing Key Lab of Earthquake Engineering and Structural Retrofit Beijing University of Technology, Beijing 100124, China

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